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ABSTRACT

The ways in which sensory information, music in particular, is managed by the mental processing system of differentially gifted students were studied. A total of 138 right-handed adolescents and young adults (aged 14 to 22 years), who were gifted in music, mathematics, or dance, were tested on two tasks of music and one task of speech perception. Focus was on studying the comparative nature of laterality patterns for music and speech perception among heterogeneously talented students. Also studied were the responses of the cerebral hemispheres to sensory stimuli and the role talent training might play in shaping ear asymmetry. Ear asymmetry for the musically gifted students seemed largely task dependent. The mathematics students possessed procedural knowledge without task content mastery, a finding that is consistent with learning taxonomies that position the skill of knowledge hierarchically before that of analysis. Results also suggest that, although each hemisphere appeared to prefer processing in differentiated form ("parts" for the left and "wholes" for the right), the two hemispheres functioned in collaboration. These findings emphasize the usefulness of initiating research combining neuroscientific and educational parameters. (SLD)

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Laterality for Music Problem Solving Among Adolescents Gifted in Music, Mathematics and Dance

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Introduction, Background and Rationale

The research study entitled *"Laterality Effects for Music Perception and Problem Solving Among Adolescents Gifted in Music, Mathematics and Dance,"* examined how sensory information, in particular, music, is managed by the mental processing system of differentially gifted students.

Specifically, 138 right-handed adolescents aged 14-22 gifted, respectively, in music, mathematics and dance were tested on two tasks of music and one of speech perception. This was done to probe the comparative nature of laterality patterns for music and speech perception among heterogeneously talented students. In effect, the questions asked were how do the cerebral hemispheres of differentially gifted students respond to sensory stimuli and how might specialized talent training play a role in shaping ear asymmetry.

The research study grew out of a need to investigate gifted students on such types of empirical tasks largely due to the fact that many studies of hemisphericity for sensory stimuli have been conducted on neurologically impaired adults. The external validity of some results had, in many cases, weak generalizability to a neurologically normal population, most particularly, students. This is an important consideration because the findings of these studies were often influential in providing theoretical bases for working psychological models of how individuals learn and remember information, a topic of special import to a student population. It was thought that by systematic empirical examination of how neurologically normal and differentially gifted students deal with musical information, useful data could be gathered pertaining to the nature of cognition, especially how information is perceived, processed, stored and retrieved and the role of talent training and learning on neural mechanisms implicated in these processes.

In addition, subsumed under the broad investigative design was another question, that of the putative similarity of musical and mathematical intelligences and, by extension, problem-solving modalities. The research study was specifically crafted to study musically and mathematically gifted adolescents in an effort to gain insight as to whether the mental mechanisms of these gifted students possessed certain aspects of correspondence in their problem-solving approaches. The performance of individuals from the talent domains of music and mathematics on tasks of music perception afforded an opportunity for evidential justification of this belief.

Finally, a unique aspect of the research study that should be noted is that under the category of musically gifted, only individuals with a primary concentration in keyboard study were included. This was done in acknowledgment of the idea that even within a single talent domain (*i.e.*, music), there may be differences among talent typology (*e.g.* vocal or instrumental training) and this, theoretically, may play a role in mental processing strategies and subsequent performance behaviors.

Research Questions

In this study, ear advantage was used to ascertain the division of labor between the two hemispheres. A right-ear/left-hemisphere advantage for a task was taken to indicate a "parts" or analytic processing modality whereas a left-ear/right-hemisphere advantage indicated a "whole" or holistic processing modality. Specifically, the following hypotheses were tested:

1. Students talented in keyboard performance, mathematics and dance would display a left-ear/right-hemisphere advantage for the processing of dichotic chords.
2. Students talented in keyboard performance and mathematics would display a right-ear/left-hemisphere advantage for the processing of dichotic melodies.
3. In contrast to students talented in keyboard performance and mathematics, respectively, students talented in dance would display left-ear/right-hemisphere advantage for the processing of dichotic melodies.

Methodology

Subjects: The research study's 138 subjects (56 males, 82 females), fell between the ages of 14-22 ($\bar{X}$= 16.8 YOA, SD 1.9 years) and were enrolled in schools, programs or conservatories in and around the New York City metropolitan area specializing in the education and training of young individuals gifted in music, dance or general academic subjects.

All subjects were dextral reporting no left-handed parent or history of hearing impairments. In addition, all possessed extensive training (on the average 8 or more years) in their respective talent domain. Students of dance and mathematics were also screened to verify a history of general non-involvement in systematic and sustained music study.

Stimuli

Subjects responded to two music tasks and one linguistic task. All music stimuli were first performed on an acoustic piano (tuned so that A4= 440 Hz) and recorded at 7.5 ips on Scotch 208 audio recording tape. They then were processed at the Haskins Laboratories in New Haven, CT where they were fed into the Pulse Code Modulation (PCM) system, digitized and stored on disk file and, finally, converted back to analog form and recorded onto magnetic tape. The speech tape was prepared at the Louisiana State University Kresge Hearing Research Laboratory of the South.

One music task (Figure 1) consisted of a dichotic chords presentation where the tonic (1st), mediant (3rd) and dominant (5th) scale degree tones of two chords (*e.g.* C Major and A Minor) are sounded simultaneously for 2 sec, that is one chord was presented to the one ear while the second chord is presented to the other ear. After a 1.5 ISI, four binaural recognition foils (2 sec long) occurred. All

tones were pitched from G3 (196.00 HZ) to G5 (783.99 Hz). There were four practice trials and 48 experimental trials with 12 sec intertrial intervals.

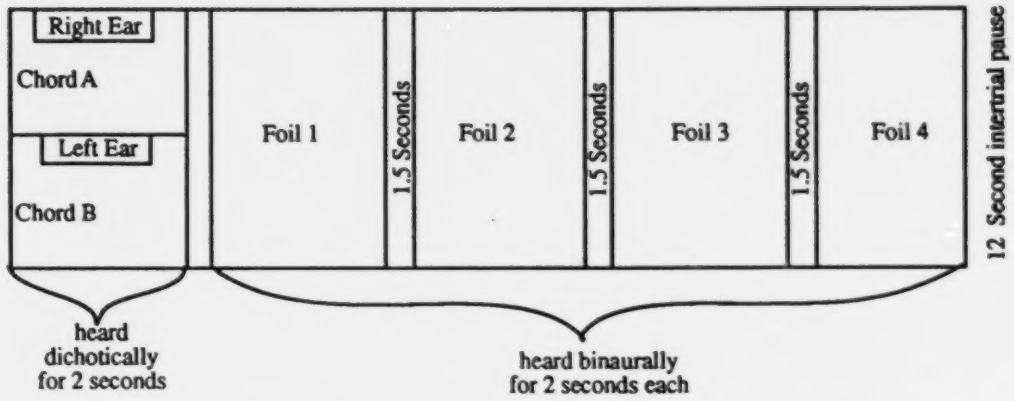

Figure 1. The dichotic chords task

The second music task, dichotic melodies (Figure 2), was comprised of music taken from a variety of compositions by Vivaldi, Handel, Bach, Mozart, and other. The entire corpus of these melody passages varied in key (major and minor) and time signature (*e.g.* 3/4, 4/4, 6/8). For each individual dichotic passage, the presentation consisted of a melody ($\overline{X}$= 7.4 sec, 11 notes) and countermelody ($\overline{X}$=7.6 sec, 13 notes). Each melody containing these passages was similar in key, tempo and pitch patterns but differed in rhythmic structure which was altered, generally, in two locations within the countermelody. There were 2 practice trials and 32 experimental trials with 12 second intertrial intervals.

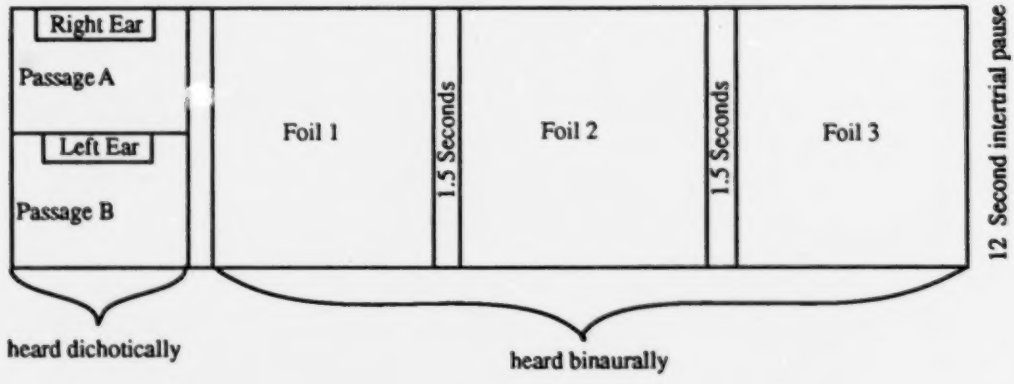

Figure 2. The dichotic melodies task

The control dichotic speech tape contained real speech tokens of the English syllables /ba/, /da/, /ga/, /ka/, /pa/, and /ta/ delivered by a male native speaker of English. There were 90 paired trials 300 msec in duration. For this task, intertrial intervals were 3 sec.

Procedure

After a reference tone (O Hz) was heard confirming proper output and operation of each channel, subjects were asked to record their responses. For all three dichotic tasks, separate answer sheets were used with subjects recording their responses with a pencil.

Subjects were presented with the speech task first to acclimate them to the type of auditory presentation utilized in the study. For this task, a free recall design requiring no ear-order of report was used. Subjects were instructed to remember the syllables presented both in the left and right ears but not necessarily to record them on the scoring sheet as having been delivered to any particular ear.

For the chords task, subjects were asked to decide which two of the four binaural chords matched an initially heard dichotic pair by marking two of the four boxes on an answer sheet. Similarly, on the melodies task, subjects were asked to indicate their choices, again on an individual answer sheet, by marking one of three boxes along with which ear they perceived the passage containing the rhythmic change to be delivered.

All stimuli were presented to subjects on a Sony Model (TC 377) two channel, reel-to-reel tape recorder which drove a set of individual stereo headphone units (Koss Pro 4).

In addition, subjects were asked to complete the Oldfield Edinburgh Handedness Instrument which determined individual handedness preference along with a Talent Background Questionnaire.

Total testing time was approximately two hours. All subjects were paid for their participation.

Results

Figure 3 showing the mean percentages of correct responses for each dichotic listening task for left and right ears among individuals in each talent domain summarizes the research study's findings. For the dichotic chords task, regardless of talent training, the hypothesized left-ear/right-hemisphere advantage was demonstrated. For the dichotic melodies, only the musically gifted students displayed a right-ear advantage. The dance and mathematics students replicated their performance on the dichotic chords task by displaying a left-ear advantage.

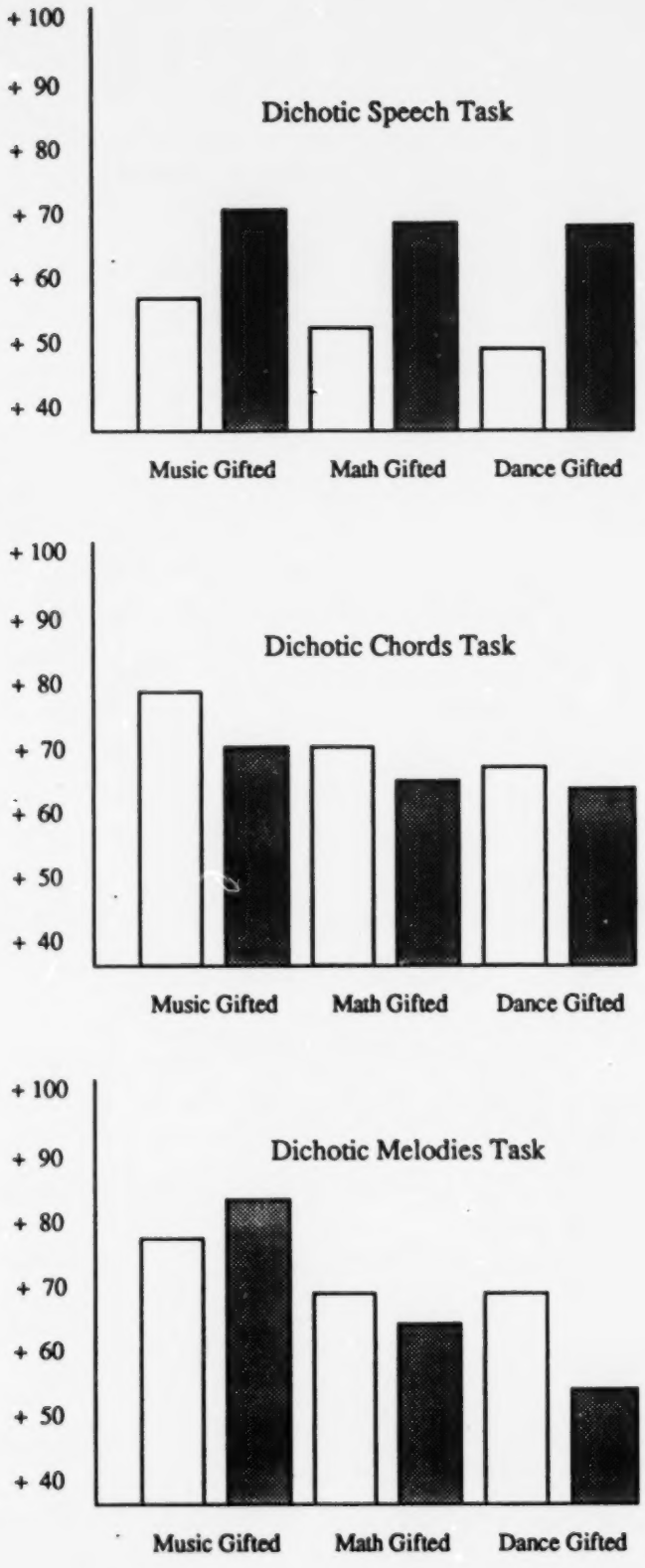

Figure 3. Mean percentage of correct responses for left-ear (LE) and right-ear (RE) in each talent group on the dichotic listening tasks

Key

White = Left Ear

Shaded = Right Ear

A series of t-tests performed across the total ear scores of each talent group on the dichotic chords task indicated a significant left-ear advantage for all talent groups. Also, individual laterality scores computed using a Laterality Index showed a left-ear advantage for all talent groups. A separate ANOVA performed on the mean scores from the chords task indicated a main effect for ear of report (*i.e.*, the left ear) very significant at the .0001 level. No Talent x Task interaction was found.

For the melodies tasks, t-tests performed on ear scores showed that only the musically trained students displayed a significant right-ear advantage for the task. Both the dance and mathematically gifted students displayed significant left-ear advantage paralleling their responses to the chords task. In addition, a separate ANOVA showed a highly significant main effect for talent ($p < .0001$) and a significant main effect for ear of report ($p < .0001$).

Chi-squares performed on the frequency distributions for each task produced essentially similar results.

Figure 4 contains data gathered on the question of similarity in ear asymmetry in musically and mathematically gifted students. Note that in the mathematically gifted students, the ear asymmetry for the chords and melodies does not reverse. Each task shows a left-ear advantage. However, for the musically gifted students, the asymmetry reverses demonstrating the functional task-dependent ear advantage and, in a larger sense, hemispheric differentiation displayed by these subjects.

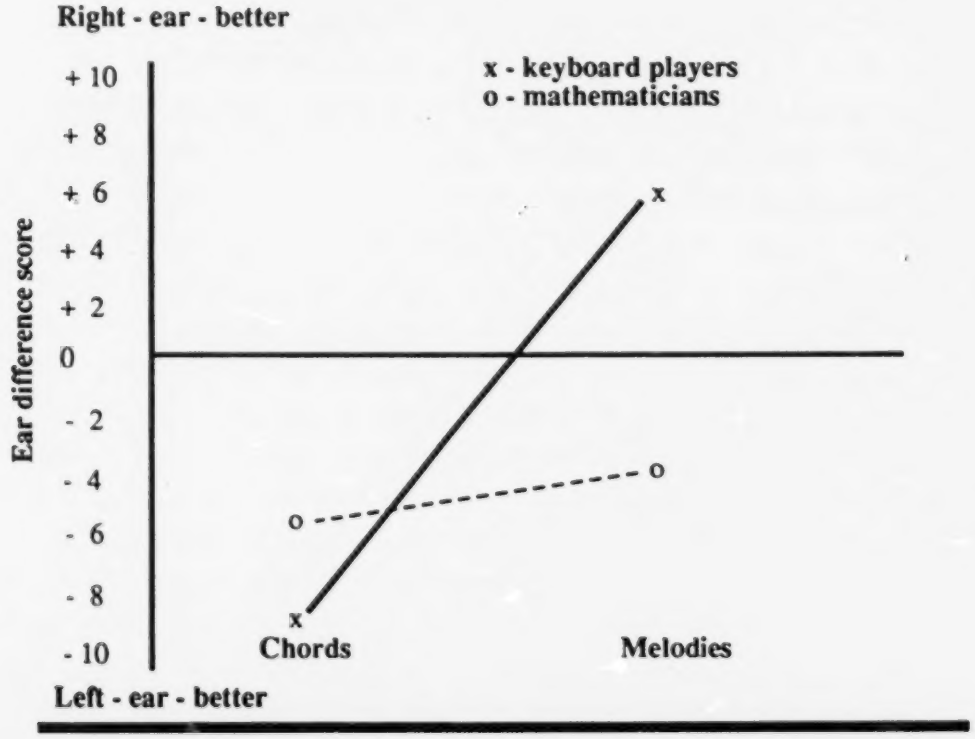

Figure 4. Ear asymmetry for dichotic music tasks using difference scores of musically and mathematically gifted students

The Meaning and Interpretation of the Findings

The principal investigatory areas of the research study centered around questions in giftedness and the neurosciences. Therefore, the implications of the study should be discussed from these vantage points.

For the neurosciences, the study involved issues relating to experimental population. On this issue, the research study served to broaden the general scope of neuropsychological inquiry by tapping a subject base comprised not of neurologically impaired adults or others classified as generically "neurologically normal," but discrete subpopulations of adolescents subsumed under the classification of "normal" screened for specific cognitive strengths. This acknowledged the idea that these strengths may play a role in the development and application of information processing strategies on a set of specific cognitive tasks. Also, the use of heterogeneously gifted populations enlarged the generalizability of neuropsychological investigations. In addition, the inclusion of only keyboard students instead of the customary "musically experienced" individuals recognized that cognitive differences may exist even among individuals of similar talent typology and attention should be paid to this issue.

As for giftedness, the research study demonstrated the potential value of research data acquired through the neurosciences. Because data were able to be collected from individuals during mentation on neurometric performance, noninferential information about special ability and the training that nurtured it and, by extension, preferential processing modalities was obtained. This contrasts with other studies of gifted individuals in which types of mental processing modalities were assessed using paper-and-pencil questionnaires or inventories outcomes of which may be an artifact of the testing situation itself.

Secondly, the study's findings show that the putative "dyadic ability" of musically and mathematically gifted individuals may not exist. Whereas ear asymmetry for the musically gifted students seemed, largely, task dependent, this was not the case for mathematically gifted students. Unlike the music students who possessed content mastery, the mathematics students may have possessed "procedural knowledge" without task content mastery. Results show that successful problem-solving for this type of task is more content than process dependent. In a sense, then, the findings converge with the inherent incremental structure of various learning taxonomies that position the skill of knowledge hierarchically before that of analysis as the manner in which the human intellect best performs.

Thirdly, results of the research study impact upon the issue of the types of curriculum and instruction designed for use with all students, especially gifted students. The findings serve to reinforce the idea that without the use of carefully formulated empirical methodologies specifically designed to measure cortical activity in students, any inferences about preferential learning modes or learning/thinking styles that translate into curriculum intervention may be precarious.

This line of thinking has been especially pervasive in current educational thought. It appears that hemispheric function has been used as a basis by which to isolate left and right "brain behavior" ascribing these behaviors as having a locus in one hemisphere of the brain sometimes typecasting students—or instruction—as either "left-brained" or "right-brained." Further, learning preferences based upon "hemispheric profiles" have resulted in suggestions that the style by which students—especially gifted student— best learn may depend upon "precocity" in either the left brain or the right.

Results of the research study suggest that although each hemisphere does appear to prefer processing in differentiated form, *i.e.* the left, "parts," and the right, "wholes," these forms are usually interdependent. Because both ears and, by extension hemispheres, were able to respond to stimuli as evidenced by total-correct scores for both ears on each dichotic task, the findings speak to the idea that for sensory events experienced in the course of a normal day by a neurologically intact individual, the two hemispheres function in collaboration and this must be at the root of any explication of human intelligence.

In closing, the findings offer encouragement for initiating additional research fusing the neurosciences and education. By increasing the data base on the role of specific areas of the cortex involved in learning, remembering and problem-solving, the precise locus of components for these cognitive behaviors may become less recondite. This, then, will serve to enrich our understanding of the entire human neurocognitive network in general, shedding light upon the questions of why we manifest communally human behaviors and, yet, continue to search out varied pathways enabling us to learn, to accomplish, and, finally, to excel.